

Diamond-based fundamental research on light-matter interaction with single photons

The emerging world of quantum technologies aims at creation and development of practical applications basing on the consequences of quantum physics. Among these one can find quantum communication, quantum computing, quantum metrology or quantum imaging. The main goal is to propose and implement solutions by taking advantage of quantum phenomena like quantum superposition or quantum entanglement. These however, can lead to very surprising and even counterintuitive implications, research on which is interesting both from fundamental and practical perspective.

In the project, light-matter interaction investigation with single photons and color centers in diamond is going to be performed. Different ways of single-photon generation are possible including quantum dots, nitrogen-vacancy centers or attenuated laser beams. The proposed project however, envisages heralded single-photon source based on spontaneous parametric down-conversion (SPDC) process. The SPDC process occurs when a high-energy photon travelling through a non-linear media spontaneously decays into two low energy photons. When spatially resolvable, the generated photons can be detected separately and the detection of one of them heralds the existence of the other one. In this way, heralded single photons can be generated and subsequently directed onto a diamond sample with color centers. Nitrogen-vacancy (NV) color centers are of particular interest thanks to their peculiar optical properties making them relatively easily accessible with single photons.

In the first part of the project, the superradiance of color centers in diamond under single-photon illumination will be analyzed. Superradiance is a quantum phenomenon where an ensemble of emitters interacts with a common light field and collective behavior is observed rather than fluorescence emission of independent emitters. The aim is to demonstrate collective emission of color centers in diamond under single-photon treatment. The second part aims at verifying the possibility of beating the diffraction limit using spatially correlated photons generated by an SPDC-based source. Resolution in standard fluorescence microscopy is fundamentally limited. Here, quantum correlations between the SPDC-generated photons are expected to beat the classical limitations, improve the resolution and enable for more detailed microscope images.